INFORMATION BEHAVIOR AMONG ACCIDENT-INVOLVED COMMERCIAL AIRLINE FLIGHT CREWS

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Human Information Behavior (HIB) is described as the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking and information use. This includes face-to-face communication as well as information reception. Individuals, as part of teams, within this system of information make decisions about information driven by rules as well as creative improvisation. There remains a weak link between actual information, the meaning given to information, and the sensemaking involved between individuals and groups. Often times commercial aviation accident reports point to a breakdown in Crew Resource Management (CRM) with no indication of *how* the breakdown occurs. This work explores how this breakdown may occur through understanding HIB in commercial airline accidents. This work uses principles of Information Science to analyze how commercial flight crews involved in accidents identify, seek, and use information, through the analysis of accident transcripts using an information grid. This work seeks to operationalize CRM measurements through understanding the social practice of information structuring and communication patterns within the distributed collective practice of the flight crew. From this, researchers may be able to identify the role information in the sociotechnical system and communication patterns that support, or render ineffectual, the infrastructure used in the negotiation of meaning on the flightdeck.

Introduction

Pilots have become agents in the transformation of data from the digitized interface into meaningful information. In the high risk, safety critical environment of aviation operations, pilots must incorporate efficient and effective communication of essential information to avoid accidents. Access to information in the modern world has been greatly improved with advances in computer technology, but the distributed use of information remains a weak link between actual information, the meaning given to information and the sense individuals and groups make of the information. This can result in miscommunication about the condition of a flight and serve as a precursor to an accident.

Consistent, procedural responses to clearly defined situations are a normal part of conducting a flight, yet there are frequently indeterminate circumstances under which crews must use their personal judgment and negotiate this meaning with members of their team to arrive at a solution. Often times accident reports point to a breakdown in Crew Resource Management (CRM) with no indication of *how* the breakdown occurs. This research investigates how crews on the flight deck of accident-involved commercial aircraft make use of information, distinguishing how breakdowns may occur through understanding human information behavior on the flightdeck.

Piloting and Technology

Stick and rudder skills, which were once the basis on which to conduct a flight, are no longer solely adequate in the technologically driven, increasingly distributed world of commercial aviation. Commercial pilots are more than mere drivers-of-airplanes as they must transform data presented to them in a myriad of digitized and auditory interfaces into a meaningful exact representation of the real world as it exists presently and as it will exist in the near future. The data pilots use to conduct a flight is highly predictable due to flight planning and known aircraft characteristics, but remains sufficiently flexible so it can be adjusted for context-specificity to serve the needs of the individual flight. Data often share common elements or arrangement, but flight data are dependent on the specific properties of the flight (e.g., weather, setting, weight, aircraft, etc.) at a specific point in time. For example, flight instruments are constantly monitored, but the frequency and pattern of monitoring depends on the state of the flight. An approach for landing requires more frequent monitoring and update of information, due to terrain proximity and obstacles, compared to straight and level flight at higher altitudes.

It is also crucial to understand the role automation plays on the advanced commercial flight deck. While there are an infinite number of situations that can occur due to the open, dynamic nature of a flight, there are limited sources a pilot can use to gather information, and even fewer when it comes to automated/invisible processes, resulting in pitting an open system against a closed one. While attempting to provide decision support, the presence of numerous displays and automated procedures on the flight deck may actually provide confounds in a system with little tolerance for these confounds (Bainbridge, 1987). The modern aircrew cannot operate without a deluge of aural, visual, and tactile alarms at any given time in the flight. In fact, the points in a flight where the majority of accidents are known to occur, approach to landing, in which air crews operate under specific procedures for communication and flight guidelines, are also the points in the flight where many alarms occur, disrupting the flow of activity and critical information (Billings, 1997).

Crew Resource Management

During the 1970s, a number of aviation accidents pointed to crew factors such as poor use of available resources (Lauber, 1979). Post accident investigation identified discrepancies in the division of duties between crewmembers, information sharing and communication as factors leading to accidents (Stone & Babcock, 1988). The airlines and the National Aeronautics and Space Administration (NASA) to developed a program known as Crew Resource Management (CRM) to combat such factors through training crews in how to address situational, sociopsychological, and other factors influencing their performance. The objective of CRM training is to improve teamwork in the areas of decision-making, communication, leadership, stress, fatigue and management (Jensen, 1995). Among other topics, CRM training teaches the process of questioning and validating information, crew briefing and debriefing, and recognizing when a crewmember may need to be removed from flight duties (e.g. when might a pilot who is second in command need to take over control of a flight to preserve safety?).

Even with this training, Dismukes, Young, and Sumwalt, (1999) note that estimates show human error contributes to 80% of all aviation accidents through such particulars as captain's authority, crew climate, and decision skills. What is needed is a way to study CRM that considers information sharing by the crewmembers, involving both internal and external cockpit communications, considered as the distributed team.

Information Infrastructure

Information science deals with both semantic and pragmatic issues of information transfer. Taylor notes that information science attempts to, "bridge the gap between theoretical areas of the communication sciences (cybernetics, artificial intelligence, self-organizing systems, and automation)…" (1963, p. 4161). Leupolt defined information science as the investigation of a specific problem or problems of/ with information by scientific means (1981, p.19). Perhaps Hoshovsky and Massey offer one of the better definitions of the field stating that, "information science is that body of knowledge, consisting of descriptions, theories, and techniques which provides understanding of the means through which society's information needs are met and which provides the understanding required to improve capabilities to define and meet such needs" (1968, p. 47). Shera (1972) relates information science with communication science by noting that information science necessarily includes all forms of communication.

Information needs necessarily vary at different stages of a process. The distinction can be made between whether information is a thing or a process, whether it is objectively or socially constructed. Buckland (1991) notes that objects such as data and documents have the qualities of imparting knowledge or communicating information, serving as information "things." An information process is more concerned with the procedure of being informed, a change in knowledge, not just the discrete form of the information "thing." While finding the "thing" is an end goal, users need to be able to get through the process, and barriers to it, of deciphering just what is that thing we need and how to get it. A person's collection of individual abilities (experience, knowledge, resources) to gather information, use the information, and communicate this knowledge is designated as their *personal information infrastructure* (Marchionini, 1995).

As we use information, we develop mental models of the skills we need to access information and to understand how that information is organized. When technology is brought into the information process, it can augment our cognitive skills by assisting in finding and using information, or technology can change the strategies we use to acquire information, confusing or disorienting us, thus impacting our abilities and performance. When interacting with information we learn to take advantage of what is easily available or understandable.

As noted in by Bishop, Neumann, Star, Merkel, Ignacio, and Sandusky (2000), users confronting a working infrastructure recognize a process of "assemblage" of artifacts, knowledge, practice and community. This assemblage involves tools arranged for a variety of users; a practical matching of work practice routines, technology and wider scale organizational and technical resources; compromises negotiated around the limits and transparency of available user knowledge; and a negotiated order in which these all function together procedurally (Bowker & Star, 1999, p. 394).

Information Behavior

Within the field of information science, Human Information Behavior (HIB) has been described as the totality of human behavior in relation to sources and channels of information, including both active and passive information seeking and information use (Wilson, 2000). This includes (face-to-face) communication as well as passive information reception (e.g., viewing TV advertisements), with no intention to act on the given information. Marchionini (1995) describes information seeking as, "a process in which humans purposefully engage in order to change their state of knowledge."

Ellis (1989; Ellis, et. al., 1993) proposes a general model of information seeking behavior as: starting, chaining, browsing, differentiating, monitoring, and extracting. *Starting* comprises activities that form the initial search for information, identifying sources that could be used for information. These sources are likely to point to, suggest, or recommend additional sources or references. *Chaining*, as a way to follow up on initial sources, can be backward or forward.

Backward chaining takes place when pointers from an initial source are followed. Forward chaining takes place through identifying and following up on other sources that refer to an initial source, thus broadening a search. *Browsing* is semi-directed or casual search in areas of potential interest. This is looking for information at the micro-event level and remaining unconstrained, or open to serendipitous findings; finding new connections or paths to information. *Differentiating* refers to filtering and selecting from among identified sources scanned, by noticing differences between the nature and the quality of the information offered. Differentiating is likely to depend on prior experiences with sources, or recommendations from others. *Monitoring* refers to keeping abreast of developments in an area through regularly following particular, or core, sources. *Extracting* is the process of systematically working through a particular source or sources to identify material of interest, directly consulting a source and using the information provided.

Modeling Information Behavior

In a study using information seeking frameworks as a background to examine the practice researchers engage in using the World Wide Web, Choo, Detlor & Turnbull (2000) focused on behavioral models of information seeking to describe the process a user follows to satisfy an information need. While this study deals with the behavior of experienced web researchers, it lends itself to adaptation into a behavioral framework with which to study HIB practice in the aviation environment. Choo, et al., incorporated a separate category of research on this topic, rooted in organizational science. Originally based on fieldwork by Aguilar (1967) and expanded by Weick and Daft (1983), this work suggests that organizations scan in four distinct modes: *undirected viewing, conditioned viewing, informal search,* and *formal search*. *Undirected viewing* refers to scanning broadly with no specific information need in mind, with the overall purpose to detect signs of early change. *Conditioned viewing* refers to viewing information about selected topics or certain types of information. The purpose is to evaluate the significance of the information in order to assess its impact on the system. *Informal search* refers to actively looking for information that involves a relatively limited and unstructured effort, to elaborate an issue and determine action. *Formal search* refers to deliberate or planned efforts to obtain specific information about particular issues, following a pre-established procedure; the search is focused and systematic.

In their study, Choo, et. al., amplified the information seeking implications of each of the aforementioned modes by combining the aspects of these models into a multidimensional framework which expands the principles of scanning and the amount and kind of effort expended (Figure 1). The four scanning modes are situated on one axis with the categories of information seeking behavior identified by Ellis on the other.

Scanning Modes	**Information**		
	Need	**Seeking**	**Use**
Undirected Viewing	General areas	Sweeping	Browsing
Conditioned Viewing	Topics of interest	Discriminat-ing	Leaning
Informal Search	Formulate queries	Satisfying	Selecting
Formal Search	Specify targets	Optimizing	Retrieving

Figure 1: Modes of scanning (from Choo, Detlor & Turnbull, 2000).

Choo, et.al. (2000) conclude that each mode of information seeking is distinguished by the ways in which users employ recurrent search tactic sequences. The knowledge workers in the study employ multiple and complimentary methods of information behavior, with differing motivations and tactics, to collect data. These tactics range from undirected when there is no specific need to be discovered, to formal focused information used in decision-making or formation of an action plan. Adapting this work to map the information behavior of the distributed aviation crew in the context of the flight deck environment may provide a window through which to view the operational needs of the crew, and allow for the development of improved infrastructure and training methods in the real world of commercial aviation operations.

Method

In a previous study (von Thaden, 2003) modes of scanning were developed into an information behavior grid to model the distributed information seeking practice of flightcrews using discourse analysis. Expanding upon the work of Choo, et. al., the information grid was developed to reflect actual practice in the aviation environment (Figure 2). This framework was adapted to examine the cockpit voice recording (CVR) portion of commercial aviation accident transcripts for HIB using qualitative discourse analysis coupled with quantitative measures. Crew discourse was analyzed for instances of information gathering or need, information seeking, and information use. These instances were then coded into the information behavior grid. The transcribed 10-minute segment from the CVR directly preceding the accident was used in the analysis.

GROUP INFORMATION GATHERING PATTERNS/NEED	GROUP INFORMATION SEEKING	GROUP INFORMATION USE
UNDIRECTED General areas monitored Informal communication/viewing No specified information need Passive attention	**DISTRIBUTED SWEEPING** Broad scan of many & various sources Detect change signals Take advantage of easy accessibility	**DISTRIBUTED BROWSING** Serendipitous discovery from a large number of different sources and different types of sources
CONDITIONED Areas of interest (trends) recognized Habitual communication/viewing patterns Passive search/recognition (schema)	**DISTRIBUTED DISCRIMINATION** Browse in pre-selected sources (instruments) using pre-specified protocols to acquire information	**DISTRIBUTED LEARNING** Increase/Communicate knowledge about areas/events of interest/relevance
INFORMAL/UNCONSTRAINED Broad search areas Simple queries formulated/addressed Active search	**DISTRIBUTED SATISFICING** Search is focused on a bounded (limited) area or instrument. A good enough search is satisfactory	**DISTRIBUTED SELECTION** Increase/Communicate knowledge on area within narrow boundaries, verify
FORMAL/METHODICAL Specific, detailed targets sought Ongoing search, update, expand	**DISTRIBUTED OPTIMIZATION** Systematic gathering of specific information, following some method or procedure (checklists)	**DISTRIBUTED EXTRACTING** Formal use of relevant information for decision making or course of action

Figure 2. The Information Behavior grid.

Discussion

The Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 2003) in accompaniment with accident data from the National Transportation Safety Board (NTSB) was used to analyze the ten-year the period from January 1990 through December 1999 for accidents in which CRM was cited as a causal factor. One hundred twenty six commercial aviation accidents with 143 CRM cause factors were discovered, out of a total of 1322 human factor related commercial aviation (defined as Part 121 and 135 carriers in the Federal Aviation Regulations) accidents for the same time period. In 48% of these accidents, some type of injury was incurred with 24% of these accidents producing fatalities. Within these 143 CRM causal factors, 63% of these accidents occurred in the preflight phase and 37% occurred during the flight. Nine of these accidents were major NTSB accident investigations with CVR transcriptions available. One transcript was deemed unusable due to the failure of the crew to pull the CVR circuit breaker resulting in the record of post accident conversation only. Of the 8 remaining accidents, 4 occurred during the final approach phase of the flight, while 4 occurred during the taxi and/or take-off phase (see Table 1). These 8 accidents also contain varied contributing factors resulting in the failure of the crew to maintain the safety of the flight.

Table 1. Varied phases and features in 8 CRM commercial accidents.

Phase	Accident*	Circumstance
Taxi	DCA91MA010A	Lost in fog
Departure	DCA94MA038	Erroneous readings, Icing, Abort above abort speed
Departure	DCA92MA025	Icing, Liftoff below speed
Departure	DCA92MA044	Erroneous readings, Improper control transfer
Approach	FTW96FA118	Gear up landing
Approach	DCA94MA027	Unstabilized approach
Approach	DCA90MA030	Controlled Flight into Terrain
Approach	DCA94MA022	Controlled Flight IntoTerrain

*NTSB Identification number. Reports available by NTSB ID on www.

The information behavior framework serves as a useful tool to investigate the qualitative factors that comprise the distributed information practice of the crew. A notable example not only of poor CRM, but poor usage of available information on behalf of the crew, delineates the usefulness of the information grid in accident analysis. On December 3, 1990, a Northwest Airlines DC-9, Flight 1482, in Romulus, MI, became lost in the dense fog while taxiing to the active runway for departure (NTSB/AAR-91/05). The flightcrew became confused about their position, yet continued on in the absence of verifiable information, halting and taxiing in an attempt to discover where they were. In such a scenario, the flight crew should have immediately stopped when they realized they were lost in the runway environment and decisively reported to air traffic control (ATC), which this crew failed to do. In addition to the flightcrew's inadequate coordination, ATC shares the burden of coordination and yet failed to issue clear and helpful instructions to the aircrew.

Coding this accident for instances of information behavior (Figure 3), illustrates a rather high percentage of verification activity (Distributed Selection, 20%). This encompasses initial movement checklists, readback, and attempts with ATC to determine the position of the aircraft. This, along with incremental instructions for movement, rather than progressive instructions, contributes to the higher percentage of communication within narrow boundaries.

Information Need	**Information Seeking**	**Information Use**
Undirected 18%	Sweeping 3%	Browsing 5%
Conditioned 1%	Discriminating 1%	Learning 11%
Informal 8%	Satisficing 14%	Selecting 20%
Methodical 6%	Optimizing 3%	Extracting 9%

Figure 3. Information behavior of Flight 1482.

The next set of behaviors involves Undirected Monitoring at 18%, which is exclusively radio coverage of other aircraft reporting and receiving instructions on the frequency. This high percentage of passive information coming into the flightdeck regarding the movement of other aircraft should have served as a vital indicator to the flightcrew that a collision could be imminent due to the volume of traffic moving about on the tarmac. Yet the crew focused on picking their way through the fog settling for what they deemed a "good enough" assessment (Satisficing, 14%), believing they had increased their awareness of the situation. What this means is the crew chose to believe they were correctly positioned in the absence of a confirmed cues stating otherwise. They chose capitalize on limited information, Casual/Informal searches (8%), coupled with "good enough" cues, and favorable discovery (Browsing, which constituted only 5%) assuring themselves through their conditioned/habitual acceptance of inadequate information (Distributed Learning, 11%). They encouraged each other to advance on chance glimpses of information without actual validation of their position through what would be expected checklist usage (Optimization, 3%) or more formal instances of systematic Extraction (9%) of relevant information to determine position or action. Six percent of the communications relating to a prescribed/methodical search are for the most part on behalf of ATC seeking more detail to clarify the disposition of the aircraft, believing the crew had some idea of where they actually were.

Ultimately, this crew wandered on to the active runway just as they decided to clarify with ATC the fact that they were lost and attempt to discern relevant information to form a plan to reestablish their position. Unfortunately, just as ATC verified their position, a Boeing 727 was bearing down on them as it continued on its takeoff roll. While it could have been a larger catastrophe, 8 people died in the accident, due to one crews' reluctance to follow procedure and share useful information.

Conclusions

Information must be managed, updated, and monitored through the practice of the crew. Using principles from information science to assess the information infrastructure on the flightdeck may shed a new light on crew practice to determine exactly what behaviors lead crews astray and set the course for disaster. Rather than CRM training scenarios consisting of the usual technical problems, crew training may need to reflect the content of the distributed crew knowledge process data to aid in creating understanding of distributed information practice on the flightdeck. Early results of this research are promising, suggesting that the focus on crew information behavior may shed light on the procedure of crew information practice that results in the end goal of a change in knowledge, not just the obtaining an information "thing." Crews need to be able to get through the process, and barriers to it, of deciphering just what is the needed information "thing" and how to get it.

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